

Time and Cosmic Clock

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Reappraisal of the standard models (SM) of fundamental forces (renormalizable gauge theory) and the large scale structure of the universe (i.e. hot big-bang scenario) has been motivated by observations like high precision electroweak measurements, quark-gluon plasma, neutrino oscillations, supernova Hubble diagrams and fluctuations in the cosmic microwave background, as well as hitherto unresolved conceptual problems. A strong belief has emerged that the classical notion of space-time (a la general relativity or GR) at Planck epoch in the early universe breaks down, and that quantum mechanics (QM) may not be valid near black holes. Many speculations have been inspired with the aim of developing a theory of everything. Though reluctantly, anthropic principle has also been invoked. A nice discussion by Dine with emphasis on effective field theories [1], Hogan's candid review in the context of the anthropic principle [2], and first two chapters of [3] on the foundational issues in the unified theories are referred for details. In this essay, I propose to present a radical yet simple approach founded on the space-time interaction hypothesis (STIH) [4].

There are numerous extrapolations beyond the SM, and it is not clear at present which one is preferred by nature. I have argued that in the progress of science at some stage a simple and pure speculative idea (fundamental postulate or FP) resolves outstanding problems and gives a new direction to the scientific thought [5]. Quantized space-time is one such idea holding hope for 'a new revolution' [6], but being based on quantizing the gravity I do not share optimism for its present form. Treating QM and relativity as FPs, a fresh look on their foundations is suggested. The well known problems extensively discussed in the literature are: physical reality of the wave-function and incompleteness arguments of EPR in QM, the provisional role of the energy-momentum tensor term in the Einstein field equation recognised by Einstein himself [7], and the role of physical experiences in GR [8]. Instead of them, one single concept that could be the source of many problems is that of time. However, I will not discuss the questions like unambiguous definition of time operator and tunneling time in QM, and the difficulties arising from the difference between the time used in QM and GR; the attention will be focussed on the new concept of time [9].

Special relativity (SR) is claimed to have discarded Newton's absolute time. Is it true? We follow Einstein's own presentations to examine this claim. Motion is a pre-supposed concept, and assuming uniform motion inertial frame (K) is postulated. According to him, if the time of an event is K^1 is the same as the time in K then it is absolute. Instantaneous signals and the clocks unaffected by motion are needed to make this absolute time physical. Since no such signals/clocks exist time is not absolute. Postulating the constancy of the velocity of light in vacuum, a scheme to measure time is proposed. In a frame K , a family of clocks $\{U_n\}$ relatively at rest are placed at all points of space. The light signal from one of the clocks U_k sent at the instant t_k travels in vacuum to U_l placed at a distance dl_k which is now set to indicate the time $t_l = t_k + dl_k/c$. The set of inertial frames $\{K_n\}$ is regulated in this way. The simultaneity of events is related by clock synchronisations, and the time specification depends on the space of reference. Reading Newton [10] it becomes clear that he is precise in making the difference between absolute and relative for space, time and motion. Einstein's concern is with the measurement of relative time. What is the meaning of the instant t_l recorded by the clock U_l ? Einstein is silent on this, and later expositions/criticisms have not thrown any light on this question [5, 9]. Reichenbach tries to define it using a signal which can be marked distinctly; ascertaining the marks a temporal sequence is established. He is unable to propose any physical signal with this property, and memory, logical decision-making and instantaneous response are the attributes assumed for the hypothetical detection device. Bunge identifies 'protophysics' in SR, and terms Newtonian absolute time as metaphorical but fails to free SR from what he terms misinterpretations. Recalling Cajori's remark that absolute time is a metaphysical concept for Newton, we conclude that SR does not address the problem of the nature of time.

The problems gets worse in GR; shown in a dramatic way by Gödel's rotating universe. Time-like and null vectors are used to get time directionality, but it is found that no time coordinate exists at each space-time point that increases as one moves in a positive time-like direction. Einstein dismisses Gödel universe as unphysical but accepts the difficulty of time ordering in relativity [10]. In cosmology, it is possible to make mathematically precise definition of homogeneity and isotropy using isometry of the metric and congruence of time-like curves [12], but physically it

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corresponds to usual world-view of $3 + 1$ dimensions. Assumption of local comoving frames and ideal clocks not only fails at the big-bang singularity and near massive bodies, it is not justified for a theory purporting to be a fundamental theory [9]. Finally I refer to a new paradox pointed out in 1988 [9]: The most significant direct evidence for SR comes from the observed enhanced lifetime of a fast moving unstable particle (e.g. muon). Decay is an irreversible process, and relativistic time dilation arises in a time-reversal symmetric kinematics. Equality of unidirectional lapse of time (lifetime) with time dilation leads to a paradoxical situation.

Departing from the contemporary trend accepting relativistic world-view, absolute nature of time is proposed based on STIH stated as: Time is the primeval cause transforming the source (or primordial) space into the physical space ($S \otimes P$).

Source space is inert, time ceaselessly transforms this into active or manifest universe i.e. the pre-universe state or beyond it is that called the source space. This transformation represents the flow of time, and all changes in the universe take place with reference to this time, hence it is absolute. Time is unidirectional due to irreversible process $S \otimes P$. In any physical measurement, the direct observations correspond to the counting of spatial lengths and spatial relations which are related to the physical quantities based on a calibration procedure. Thus irreducible part of any measurement is counting of a unit of length, and for observed three dimensional space a reasonable measure is its volume. A measurable duration of elementary time interval for successive action transforming $S \otimes P$ can be equivalently used. Let the volume V_e is transformed in a duration of time interval t . Simplest choice is to assume creation of equal volume V_e in each time step t . Noting the importance of the concept of energy, we may endow the source space with fundamental energy, and express V_e and t in the units of energy. Assuming Planck constant as a unit conversion factor, the energy in volume V_e is h/t , and energy density ρ

$$\rho V_e = h/\tau \quad (1)$$

The volume of the universe at time $T = N\tau$, (N is an integer) is

$$V(T) = V_e T/\tau \quad (2)$$

For sufficiently large N , a continuous variable t may be used instead of T .

To build a simple model, we assume spherical (spatial) universe. Incremental radius ΔR from $(N - 1)\tau$ to $N\tau$ is given by

$$\Delta R = R(N\tau) - R[(N - 1)\tau] \quad (3)$$

For large N , following expressions are easily obtained

$$\frac{dR}{dt} = \frac{1}{3}\lambda t^{-2/3} \quad (4)$$

$$\frac{d^2 R}{dt^2} = -\frac{2}{9}\lambda t^{-5/3} \quad (5)$$

where the constant

$$\lambda = \left(\frac{3V_e}{4\pi\tau} \right)^{1/3} \quad (6)$$

Interesting physical consequences follow from this model [3] assuming t equal to Planck time ($\approx 5.5 \times 10^{-44} \text{sec}$), and imposing the condition that at any time the maximum velocity is limited by the cosmic expansion rate Eq.(4). Taking input data, age of the universe [13] 12.5 billion yrs and velocity of light equal to dR/dt at present, the size of the universe in the first instant is calculated to be $\approx 108 \text{ cm}$, in contrast to Planck length in big-bang model. Equation (1) gives the value of the energy density, and again treating c as a unit conversion factor, we can express it in equivalent mass density ($\approx 5 \times 10^{-30} \text{gm/cm}^3$). Equating the acceleration due to gravity of the total energy of the universe on itself of Newtonian gravitation by Eq.(5), the value of gravitational constant G can be determined. In this case, both age of the universe and r can be derived assuming the known values of G and c . Evidently, in this model

$$G(t) \propto t^2 \quad (7)$$

$$c(t) = \frac{dR}{dt} \propto t^{-2/3} \quad (8)$$

Time variation of physical constants has been discussed e.g. by Dirac and now in the context of compactification of the extra dimensions in Kaluza-Klein/superstrings. As an alternative to inflationary model [14], time varying light velocity cosmologies have recently been proposed [15]. Unlike them, our approach does not give a fundamental role to the velocity of light. In fact, a cosmic clock gives an absolute measure of time, and cosmic expansion rate regulates the physical processes. Using empirical observations on time variations of c and G , stringent limits on the unknown parameters in our model like r and age of the universe can be obtained.

Radial expansion and internal oscillations/rotations constitute basic dynamical processes. Elementary entities are proposed to be the spatio-temporal bounded structures with characteristic sizes DR at different epoch create many such species: at 1 sec $DR \approx 10 - 21$ cm and at 1010 yrs it is $\approx 10 - 33$ cm. Lumps of aggregates of these elementary species is matter in this scenario. A significant development in STIH is envisaged with the proposition that electronic charge is a manifestation of fractional spin $e/2$ of a 2+1 dimensional model of electron [3], see also discussion in [16]. In contrast to the question asking how to get 4D from higher dimensions, we find 2D structures in the 3D space. The fractional spin has different values for different DR created at different moments during the evolution of the universe, therefore the spatial location of the planet earth and its age determine the values of the coupling constants (like fine structure) and the existence of life here, however species with different coupling constants may have formed varied structures elsewhere (e.g. in the extra-galactic universe).

Incorporating interaction (spin origin) and using statistical mechanics to understand the structure of the universe are the problems deserving attention, though the slow progress in STIH has been mainly due to efforts of the author in isolation. A measure manifold for the cellular structure of space-time in unimodular gravity [17] appears a promising candidate for enunciating an extremum principle.

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